

What is claimed is:

1. A semiconductor device having a MEMS,
2 comprising:
3 a semiconductor substrate on which an
4 integrated circuit is formed; and
5 a plurality of units which are formed on said
6 semiconductor substrate and comprise movable portions
7 that physically move on the basis of a first electrical
8 signal,
9 each of said units comprising at least
10 a control electrode which supplies a control
11 signal for causing the movable portion to physically
12 move,
13 a driving circuit which outputs the control
14 signal to the control electrode on the basis of the
15 first electrical signal,
16 a sensor electrode which detects physical
17 motion of the movable portion,
18 a sensor circuit which generates a second
19 electrical signal corresponding to physical motion of
20 the movable portion on the basis of a signal from the
21 sensor electrode,
22 a memory which holds an externally input
23 setting value, and
24 a processor which generates the first
25 electrical signal on the basis of the setting value held

26 in the memory, and controls output of the control signal
27 from the driving circuit on the basis of the generated
28 first electrical signal and the second electrical
29 signal, thereby controlling operation of the movable
30 portion,

31 wherein the driving circuit, the sensor
32 circuit, the memory, and the processor are constituted
33 by part of the integrated circuit.

2. A device according to claim 1, wherein
2 the movable portion includes a mirror which is
3 rotatably coupled to a mirror substrate,

4 the mirror substrate is supported by a support
5 member which is formed from a conductive material on
6 said semiconductor substrate via an interlayer
7 dielectric layer,

8 the control electrode and the sensor electrode
9 are arranged on the interlayer dielectric layer below
10 the mirror so as to be insulated from the support
11 member, and

12 the mirror is arranged at a predetermined
13 distance above the control electrode and the sensor
14 electrode.

3. A device according to claim 2, wherein the
2 sensor electrode is arranged outside the control
3 electrode in a region below the mirror.

4. A device according to claim 2, wherein the
2 control electrode is arranged outside the sensor
3 electrode in a region below the mirror.

5. A device according to claim 2, further
2 comprising an insulating resin protective film which
3 covers an upper surface of the control electrode.

6. A device according to claim 2, further
2 comprising an insulating resin protective film which
3 covers an upper surface of the sensor electrode.

7. A method of manufacturing a semiconductor
2 device having a MEMS, comprising the steps of:
3 forming an integrated circuit including a
4 processor, a memory, a driving circuit, and a sensor
5 circuit on a semiconductor substrate;
6 forming an interlayer dielectric layer on the
7 semiconductor substrate;
8 forming in a plurality of unit regions on the
9 interlayer dielectric layer a plurality of control
10 electrodes and a plurality of sensor electrodes which
11 are insulated from each other;
12 forming a support member from a conductive
13 material on the interlayer dielectric layer so as to
14 become higher than the control electrode;

15 preparing a mirror substrate which comprises
16 mirrors in a plurality of opening regions and is formed
17 from a conductive material, the mirrors being pivotally
18 coupled to the mirror substrate via coupling portions;
19 and

20 connecting and fixing the mirror substrate
21 onto the support member to arrange the mirrors of the
22 mirror substrate at an interval above the control
23 electrodes and the sensor electrodes which are formed
24 for the plurality of units,

25 wherein the control electrodes are
26 electrically connected to the driving circuit so as to
27 receive a signal from the driving circuit, and

28 the sensor electrodes are electrically
29 connected to the sensor circuit so as to output a signal
30 to the sensor circuit.

8. A method according to claim 7, wherein before
2 the mirror substrate is connected and fixed onto the
3 support member, a predetermined resin pattern is formed
4 by stencil printing to form a protective film which
5 covers at least top of the control electrode.

9. A method according to claim 7, wherein before
2 the mirror substrate is connected and fixed onto the
3 support member,
4 a photosensitive resin pattern which covers

5 the control electrode is formed by stencil printing, and
6 the resin pattern is patterned by
7 photolithography to form a protective film which covers
8 at least top of the control electrode.

10. A method of manufacturing a semiconductor
2 device having a MEMS, comprising at least the steps of:
3 forming an integrated circuit including a
4 processor, a memory, a driving circuit, and a sensor
5 circuit on a semiconductor substrate;
6 forming an interlayer dielectric layer on the
7 semiconductor substrate;
8 forming in a plurality of unit regions on the
9 interlayer dielectric layer a plurality of control
10 electrodes and a plurality of sensor electrodes which
11 are insulated from each other;
12 forming a support member from a conductive
13 material on the semiconductor substrate via an
14 insulating film so as to become higher than the control
15 electrode;
16 forming a mirror substrate from a conductive
17 material on the support member while holding a space
18 above the control electrodes and the sensor electrodes;
19 and
20 forming, in the plurality of unit regions,
21 opening regions which pass through the mirror substrate,
22 and forming, in the opening regions, mirrors which are

23 pivotally coupled to the mirror substrate via coupling
24 portions,
25 wherein the mirrors formed on the mirror
26 substrate in the unit regions are arranged at an
27 interval above the control electrodes and the sensor
28 electrodes,
29 the control electrodes are electrically
30 connected to the driving circuit so as to receive a
31 signal from the driving circuit, and
32 the sensor electrodes are electrically
33 connected to the sensor circuit so as to output a signal
34 to the sensor circuit.

11. A method of manufacturing a semiconductor
2 device having a MEMS, comprising the steps of:
3 forming an integrated circuit including a
4 processor, a memory, a driving circuit, and a sensor
5 circuit on a semiconductor substrate;
6 forming on the semiconductor substrate an
7 interlayer dielectric layer which covers the integrated
8 circuit;
9 forming a seed layer on the interlayer
10 dielectric layer;
11 forming on the seed layer a first sacrificial
12 pattern having openings in a first region, a plurality
13 of second regions, and a plurality of third regions;
14 forming on the seed layer exposed in the

15 first, second, and third regions a first metal pattern
16 substantially equal in film thickness to the first
17 sacrificial pattern by plating, and a second metal
18 pattern and a third metal pattern not larger in film
19 thickness than the first metal pattern;
20 after forming the first, second, and third
21 metal patterns into predetermined film thicknesses,
22 forming on the first sacrificial pattern and the second
23 and third metal patterns a second sacrificial pattern
24 having an opening in a fourth region on the first metal
25 pattern;
26 forming a fourth metal pattern substantially
27 equal in film thickness to the second sacrificial
28 pattern by plating on a surface of the first metal
29 pattern that is exposed in the fourth region;
30 after forming the fourth metal pattern into a
31 predetermined film thickness, removing the first and
32 second sacrificial patterns;
33 after removing the sacrificial patterns,
34 selectively removing the seed layer by using the first,
35 second, and third metal patterns as a mask, thereby
36 forming a support member from a layered structure of the
37 first and fourth metal patterns, a plurality of control
38 electrodes which are formed from the plurality of second
39 metal patterns and separated from each other on the
40 interlayer dielectric layer, and a plurality of sensor
41 electrodes which are formed from the plurality of third

42 metal patterns and separated from each other on the
43 interlayer dielectric layer;
44 preparing a mirror substrate which comprises
45 mirrors in a plurality of opening regions and is formed
46 from a conductive material, the mirrors being pivotally
47 coupled to the mirror substrate via coupling portions;
48 and
49 connecting and fixing the mirror substrate
50 onto the support member to arrange the mirrors of the
51 mirror substrate at an interval above the control
52 electrodes and the sensor electrodes,
53 wherein the control electrodes are
54 electrically connected to the driving circuit so as to
55 receive a signal from the driving circuit, and
56 the sensor electrodes are electrically
57 connected to the sensor circuit so as to output a signal
58 to the sensor circuit.

12. A method according to claim 11, wherein before
2 the mirror substrate is connected and fixed onto the
3 support member, a predetermined resin pattern is formed
4 by stencil printing to form a protective film which
5 covers at least top of the control electrode.

13. A method according to claim 11, wherein before
2 the mirror substrate is connected and fixed onto the
3 support member,

4 a photosensitive resin pattern which covers
5 the control electrode is formed by stencil printing, and
6 the resin pattern is patterned by
7 photolithography to form a protective film which covers
8 at least top of the control electrode.

14. A method of manufacturing a semiconductor
2 device having a MEMS, comprising the steps of:
3 forming an integrated circuit including a
4 processor, a memory, a driving circuit, and a sensor
5 circuit on a semiconductor substrate;
6 forming on the semiconductor substrate an
7 interlayer dielectric layer which covers the integrated
8 circuit;
9 forming a seed layer on the interlayer
10 dielectric layer;
11 forming on the seed layer a first sacrificial
12 pattern having openings in a first region, a plurality
13 of second regions, and a plurality of third regions;
14 forming on the seed layer exposed in the
15 first, second, and third regions a first metal pattern
16 substantially equal in film thickness to the first
17 sacrificial pattern by plating, and a second metal
18 pattern and a third metal pattern not larger in film
19 thickness than the first metal pattern;
20 after forming the first, second, and third
21 metal patterns into predetermined film thicknesses,

22 forming on the first sacrificial pattern and the second
23 and third metal patterns a second sacrificial pattern
24 having an opening in a fourth region on the first metal
25 pattern;
26 forming a fourth metal pattern substantially
27 equal in film thickness to the second sacrificial
28 pattern by plating on a surface of the first metal
29 pattern that is exposed in the fourth region;
30 after forming the fourth metal pattern into a
31 predetermined film thickness, forming on the second
32 sacrificial pattern a mirror substrate which is
33 electrically connected to the fourth metal pattern and
34 formed from a conductive material;
35 forming a through hole in the mirror
36 substrate, and forming in a plurality of predetermined
37 regions of the mirror substrate a plurality of mirrors
38 which are pivotally coupled to the mirror substrate via
39 coupling portions;
40 removing the first and second sacrificial
41 patterns via the through hole formed in the mirror
42 substrate; and
43 after removing the sacrificial patterns,
44 selectively removing the seed layer via the through hole
45 by using the first, second, and third metal patterns as
46 a mask, thereby forming a support member from a layered
47 structure of the first and fourth metal patterns, a
48 plurality of control electrodes which are formed from

49 the plurality of second metal patterns and separated
50 from each other on the interlayer dielectric layer, and
51 a plurality of sensor electrodes which are formed from
52 the plurality of third metal patterns and separated from
53 each other on the interlayer dielectric layer,
54 wherein the mirrors formed on the mirror
55 substrate are arranged at an interval above the control
56 electrodes and the sensor electrodes,
57 the control electrodes are electrically
58 connected to the driving circuit so as to receive a
59 signal from the driving circuit, and
60 the sensor electrodes are electrically
61 connected to the sensor circuit so as to output a signal
62 to the sensor circuit.